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ABSTRACT

Three design strategies for selecting number of instructional instances needed in concept learning were investigated. Two strategies used adaptive procedures for the selection, while a nonadaptive strategy selected instances by number of associated attributes. The data analysis showed that the full adaptive strategy (using pretask and on-task response data) required 25% less learning time and resulted in better posttest performance ($p < .01$) than the partial adaptive strategy (pretask data only). The partial adaptive strategy was 16% more efficient and demonstrated better performance ($p < .01$) than the nonadaptive. An effectiveness ratio of 2 to 1, in favor of the full adaptive over the partial and nonadaptive strategies, was obtained. (Author)

# Computer-Based Adaptive Instructional Strategies for the Improvement of Performance and Reduction of Time

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## Abstract

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Researchers investigating concept acquisition demonstrated a consistent set of design strategies useful in facilitating the learning of concepts (Houtz, Moore, & Davis, 1973; Klausmeier, 1976; Klausmeier, Ghatala, & Frayer, 1974; Merrill & Tennyson, 1977; Stolurow, 1975; Tennyson, Steve, & Boutwell, 1975). Design strategies derived from this research literature include the following components: (a) presentation of the defining (rule) statement in terms of critical attributes, (b) presentation of positive instances which show a divergence of the variable attributes (critical attributes associated with subordinate concepts), (c) presentation of positive and negative instances which show a matching of variable attributes, and (d) presentation of instances of varying difficulty ratings. A design strategy for selecting an appropriate number of instructional instances was proposed by Markle and Tiemann (1969). The number of instances, referred to as a rational set, is based upon the number of defined critical attributes and variable attributes of the concept.

Klausmeier and Feldman (1975) investigated the number of instances needed in conceptual learning, by varying the number of rational sets presented in an experimental learning task. The design strategy used by Klausmeier and Feldman follow Markle and Tiemann's (Note 2) proposal and practice in identifying instances is necessary "full" concept mastery. Klausmeier and Feldman

hypothesized that selecting the number of instructional instances be determined by the number of defined critical and variable attributes as well as a set of practice sets. The results of their study did not show a difference on posttest scores between a treatment condition composed of a minimal number of instances (one rational set of eight instances) and a practice condition with three rational sets (24 total instances). However, it would appear from the Klausmeier and Feldman (1975) study, that selecting the number of instances is not necessarily contingent upon the number of defined attributes or practice sets; rather, the number of instances selected for instruction might be based upon individual learning differences (pretask capability and achievement) and individual learning needs (on-task learning requirements).

The purpose of this study was to investigate a design strategy for selecting number of instances that would take into account both pretask individual student aptitude and attitudinal differences and on-task learning needs while maintaining an established standard of mastery. Implicit is that effectiveness in concept learning can be obtained by an adaptive design strategy that provides a process for adjusting the basic learning environment (and in this case, number of instances presented) to the unique learning characteristics and needs of each student.

Tennyson (1975) proposed an adaptive design strategy that would select instances in a concept learning task by analyzing a student's on-task error patterns. In a refinement of that strategy, Rothen and Tennyson (in press) designed a computer-based adaptive management strategy that uses Bayes' theory of conditional probability to select an instructional sequence according to individual student characteristics and needs. The functional operation of that adaptive design strategy is related to guidelines described by Novick and

Lewis (1974) for determining the minimal length of posttests adequate to provide sufficient information regarding the learner's degree of mastery of the behavior being tested. In this study modifications to this standard Novick and Lewis (1974) methodology were made such that a definite rule or algorithm selects number of instances from a table of generated values. In addition, this procedure is applied iteratively until either the student is judged to have mastered the objective or the instructional instances pool is exhausted.

This research tests the premise that the number of instances necessary in a concept learning task can be determined by individual differences and need; we hypothesized that an adaptive design strategy (in this case using Bayes' theory) that uses premeasure (aptitude), pretest (prior achievement), and ontask performance (learning) data would result in more effective concept learning than an adaptive model that uses only pretask (premeasure and pretest) data. (Effective learning is defined as student ability to perform skillfully and economically.) We further hypothesized that both the full (pretask and ontask measures) adaptive design strategy and the partial (pretask only) adaptive design strategy would result in better effectiveness than a nonadaptive strategy (the number of instances selected according to number of critical and variable attributes and practice sets).

## Method

### Students and Design

Participants (N-67) were undergraduate male and female students from the general psychology subject pool at the University of Minnesota. Students were given course credit for participation in this study. A one-way experimental design consisting of three treatment conditions was used with multivariate

analysis of covariance. The three experimental conditions were (a) an adaptive model which used pretask and ontask data to select number of instances, (b) a partial adaptive model which used only pretask data for selecting number of instances, and (c) a nonadaptive model which consisted of a set number of instances determined by number of critical and variable attributes (Klausmeier, 1976). Dependent variables were correct scores on the posttest, ontask learning time, and an effectiveness score (a ratio calculated by dividing the posttest score by the ontask time).

Learning Program

Two legal concepts associated with court decision-making were used in the learning program: best evidence rule and hearsay. The learning program required that the student assume the role of the judge in a civil case in a Federal District Court and rule on objections to questions asked to witnesses, by either the plaintiff's or defendant's lawyer. The instances were written so that the student had to respond to the objection by identifying it as best evidence rule, or hearsay, or overrule.

Treatment programs. Three computer-assisted instruction treatment programs were developed as follows:

Program one used the full Bayesian adaptive model to select number of instances to be presented to each student individually. That is, the pretask data (premeasure score on syllogisms and pretest score) established a prescribed number of instances for the learning task while student ontask responses modified that prescription.

Program two consisted of a partial Bayesian adaptive model which used only the pretask information to determine number of instances. The premeasure and pretest scores provided the data to prescribe individual learning task length.

Program three was nonadaptive model in which students received the same number of instances. The number of instances per concept was determined by number of critical attributes (two), number of variable attributes (three; evidence, testimony, and assertion) and practice (two instances per attribute; Klausmeier, 1976). Therefore, the nonadaptive learning task consisted of 10 hearsay, 10 best evidence rule, and 10 overrule instances (30 total instances).

<u>Bayesian Probability Model</u>

Following is a description of the functional logic of the computer-based Bayesian adaptive strategy used in this research study. The strategy is a management system which determines number of instances to be presented to each student. The computer program includes a premeasure (both a performance and time measure) from which each student's loss ration was calculated. A pretest was then administered from which the prior Beta distribution was selected. From this distribution table, the number of instances was determined, while the ontask responses were used to adjust this number.

<u>Procedures</u>. Since the instructional materials for the three treatments, except for the introduction, were presented via computer terminal, the students were treated on an individual basis.

## <u>Results</u>

A multivariate analysis of covariance test was used, with ontask time and posttest correct score as dependent variables. Ontask time refers to the measured time period in which students were interacting with the learning program; this time did not include pretask time or posttest time. The posttest consisted of 20 items, eight best evidence instances, eight hearsay instances, and four forms of overrule objections. The multivariate test was significant, $\underline{U}$ (2, 1, 64) = .51, $\underline{p}$ < .001. The first contrast test tested the hypothesis

that the adaptive strategy was more effective than the partial adaptive strategy. The results showed a difference between the two conditions. $\underline{U}$ (1, 1, 64) = .66, $\underline{p}$ < .001. Contrasting the two adaptive conditions with the nonadaptive condition resulted in the hypothesize difference, $\underline{U}$ (1, 1, 64) = .63, $\underline{p}$ < .001.

Ontask time mean differences between the three treatment conditions ranged from 14.0 minutes for the full adaptive group (pretask and ontask measures for selecting number of instances) to 23.4 minutes for the nonadaptive group (number of instances selected by a rational set of critical and variable attributes and practice); with 18.8 minutes for the partial adaptive group (pretask only data used for selecting instances). Using a oneway analysis of variance, the $\underline{F}$ test was significant, $\underline{F}$ (2, 64) = 15.6, $\underline{p}$ < .0001. Two multiple range tests, Student-Newman-Keuls and least significant difference, showed that each treatment mean was different at an alpha level of .01. That is, the full adaptive group's time in finishing the learning program, a full four minutes faster than the partial adaptive group and nine minutes faster than the nonadaptive group, was significantly better than the two other groups; the five minutes difference between the partial adaptive group and the nonadaptive group was likewise significant. The analysis of variance test on pretask time, including the syllogism test, directions, and pretest, was nonsignificant (average pretask time for all groups was 17.2 minutes), $\underline{F}$ (2, 64) = .64, $\underline{p}$ < .99. Also, the $\underline{F}$-test on posttest time showed no difference between the three groups (average posttest time was 10.2 minutes) $\underline{F}$ (2, 64) = 2.10, $\underline{p}$ < .13.

Posttest correct scores (20 item test) were analyzed using the premeasure (syllogism test) as a covariate; resulting in a difference between the three group means, $\underline{F}$ (2, 63) = 15.82, $\underline{p}$ < .001. Students in the full adaptive group ($\underline{M}$ = 16.9) had a correct mean score of over four points higher than the nonadaptive group ($\underline{M}$ = 12.7). Students in the partial adaptive group ($\underline{M}$ = 14.3)

had a correct mean score that was two points higher than the nonadaptive group ($M = 12.7$). The Student-Newman-Keuls' test showed that each of the three group means were different at .05, with the least significant difference test showing a .01 difference. The pretest correct mean score $F$ test between the three groups was nonsignificant ($p > .05$).

The third dependent variable represents an effectiveness measure of the learning programs. Effectiveness is defined here as student ability to perform well and economically. The effectiveness ratio was calculated for each student by dividing the posttest correct score by the ontask time. An analysis of variance test resulted in a significant difference between the three groups, $F\,(2, 64) = 23.76$, $p < .001$. Student-Newman-Keuls' test showed that the most effective learning program used the full adaptive strategy for selecting number of instances ($p > .05$; the least significant difference was $p > .01$). Also, students in the partial adaptive group had an effectiveness mean score significantly different (Student-Newman-Keuls, $p > .05$; least significant difference, $p > .01$) from the nonadaptive group students.

## Discussion

The impact of Bayes' theory in the context of a design strategy for selecting numbers of instances, based upon a probability of mastery was shown in the ontask learning time differences between the adaptive and nonadaptive strategies. Bayes' theory in the context of an instructional design strategy provides each student with an individually selected number of instances. Furthermore, the ontask student response measurement component of the full adaptive strategy allows for continous updating of the predition of learning success, resulting in possible modifications in the selected number of

instances. We did expect ontask time differences between the three treatments, but the amount differnce (25% between the full adaptive strategy and the partial adaptive strategy, and 16% between the partial adaptive strategy and design control strategy) exceeded anticipations. The ontask iteration capability of the full adaptive strategy, in updating each student's probability of mastery, extends the aptitude- (or achievement) treatment interaction research.

Posttest performance outcomes suggest a phenomenon associated with student interest in content, once learning of the content is assumed by the student, may be operating. Students in the full adaptive group not only finished the learning task in less time than the students in the nonadaptive treatment, but they answered 85% of questions on the posttest correctly compared to only 64% for the students in the nonadaptive group. Students in the full adaptive treatment were immediately given the posttest when mastery of the task was predicted; whereas, the nonadaptive students had to remain ontask until all instructural instances were presented. We interpret these differences on the basis of elicited student interest. That is, in a learning environment where no attempt is made to adjust instructional time when learning has occured, students may lose interest (motivation) in the task which may also result in a deterioration of performance.

The effectiveness ratio was calculated in reference to the assumption that performance and learning time are major variables in assessing an instructional treatment. Research on instructional variables should demonstrate not only better learning outcomes but also more efficient learning. The effectiveness ratio between the full adaptive strategy (1.4) and nonadaptive strategy (.6) of almost 2 to 1 further demonstrates the impact of using ontask learning

measures to select number of instructional instances, especially when comparing the ratios of the partial adaptive strategy (.9) and the nonadaptive strategy (.6). This effectiveness ratio clearly shows that ontask measures for modifying an instructional length, while maintaining a specific level of mastery, can achieve significant gains in student learning over that of only pretask measures.

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